Design and Fabrication of the protoDUNE Dual Phase LArTPC

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DUNE Overview

- The **Deep Underground Neutrino Experiment (DUNE)** is a leading edge, international experiment for neutrino science and proton decay

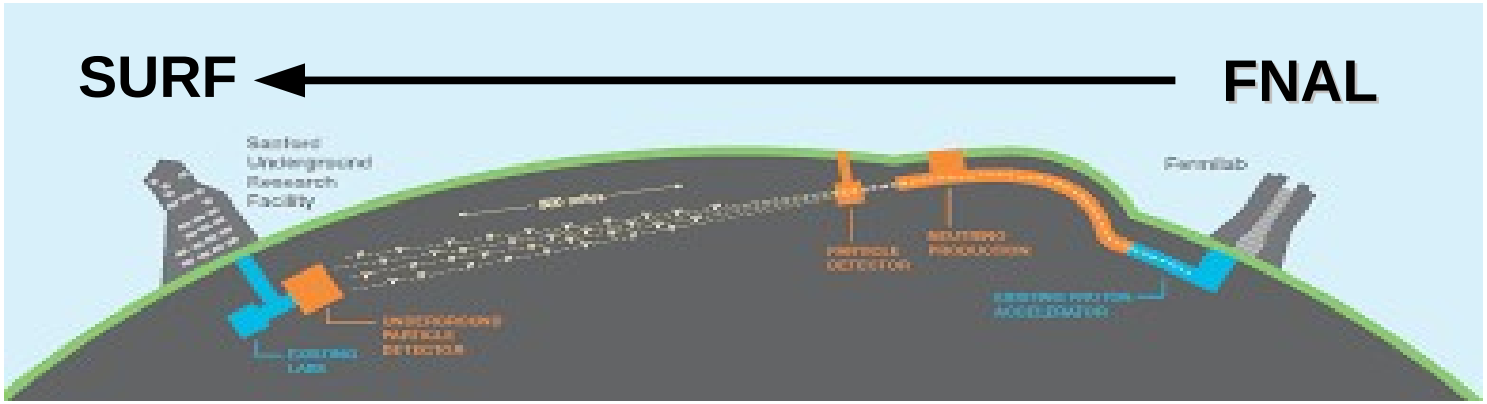
Features of DUNE:

→ **1300 km baseline : "**LBL**"**
→ **Most intense neutrino beam : "**LBNF**"**
→ **Large (40kt) LArTPC far detector and near detector**
→ **Far detector 1.5 km underground**

Primary Physics goals :

→ **ν oscillations MH, δcp, θ_{23}**
→ **Physics beyond standard model**
→ **Nucleon decay**
→ **Supernova burst neutrinos**

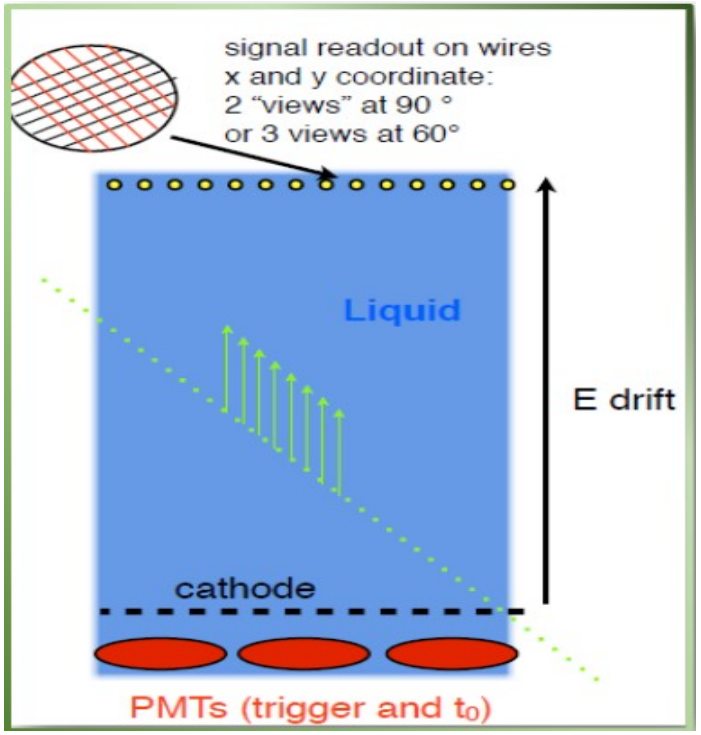
DUNE prototype LArTPC detectors are under construction at CERN



Motivation : LArTPC

- Liquid Argon Time Projection Chamber (LArTPC) is imaging detector that offers exceptional capabilities for studying neutrinos.

- **How does LArTPC Work**
  - → Charged particles interact with Ar produces electrons and scintillation light
  - → Ionization electron drifts toward the anode
  - → Imaging is provided by wire planes or a micro-pattern structure placed at the end of the drift path



- The DUNE experiment will address the next major questions in neutrino physics using giant neutrino detectors

- proto type LArTPCs currently considered within DUNE are
  - * The protoDUNE Single-Phase
  - * **The protoDUNE Dual-Phase**

Motivation:The Dual-Phase LArTPC

- **Neutrino Experiment requires massive detectors → Very long drifts**
- **Long drifts requires ultra high purity → charge attenuation**
- **No charge amplification in single phase**

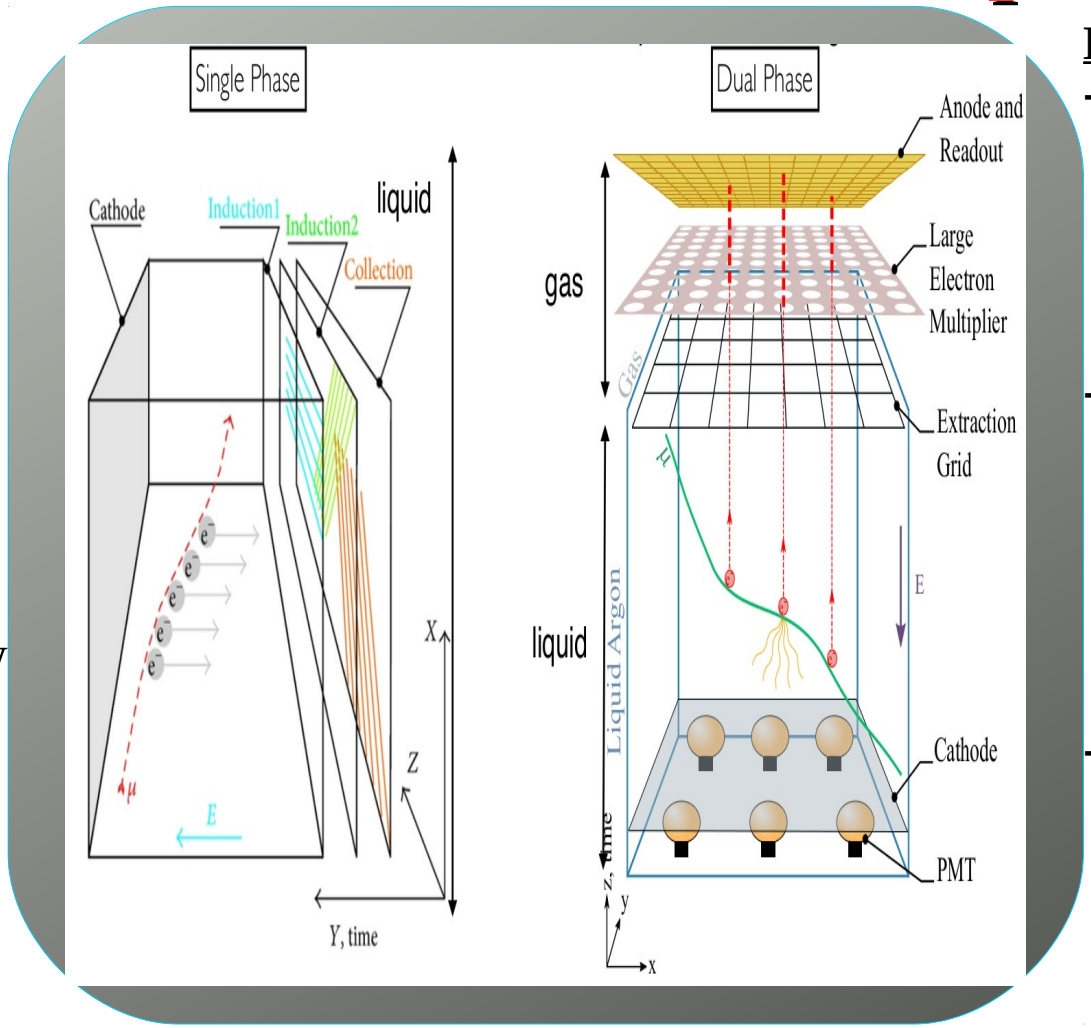
The Dual-Phase LArTPC :

- **The Dual-Phase (DP) LArTPC refers to the extraction of ionization electrons at the interface between liquid and gaseous argon and their amplification and collection at the gaseous phase**
- **Key-feature**
  - **→ Amplification of the signal by charge avalanche in the gas phase**
  - **→ Large signal/noise ratio**
  - **→ Allow constructing detectors with large drift**
  - **→ overall good image quality**

The Dual-Phase Concept

Single Phase

- Ionization and collection in the same phase
- Read out by wires, one collection view and one or more induction view
- No amplification of the initial ionization signal

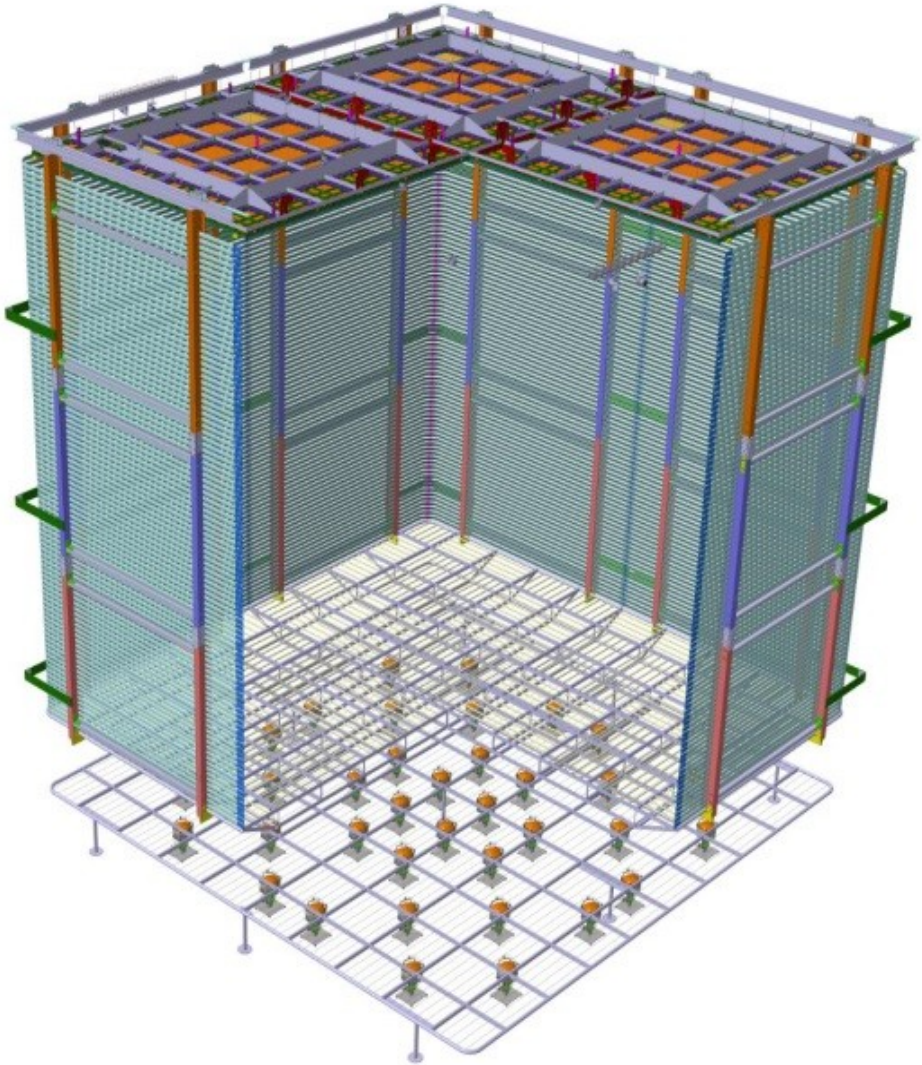


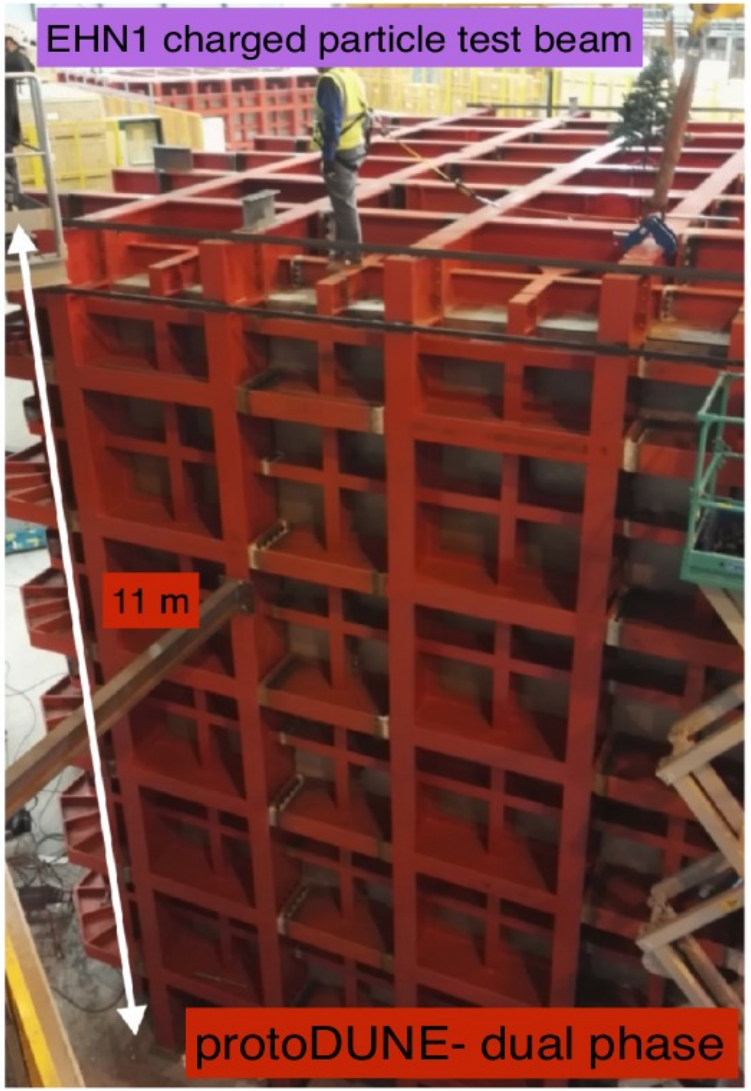
Dual Phase

- Ionization in liquid argon and collection in the gaseous phase
- Extraction of the electrons to the gas phase from the liquid level
- Avalanche multiplication of the electrons in the pure argon gas

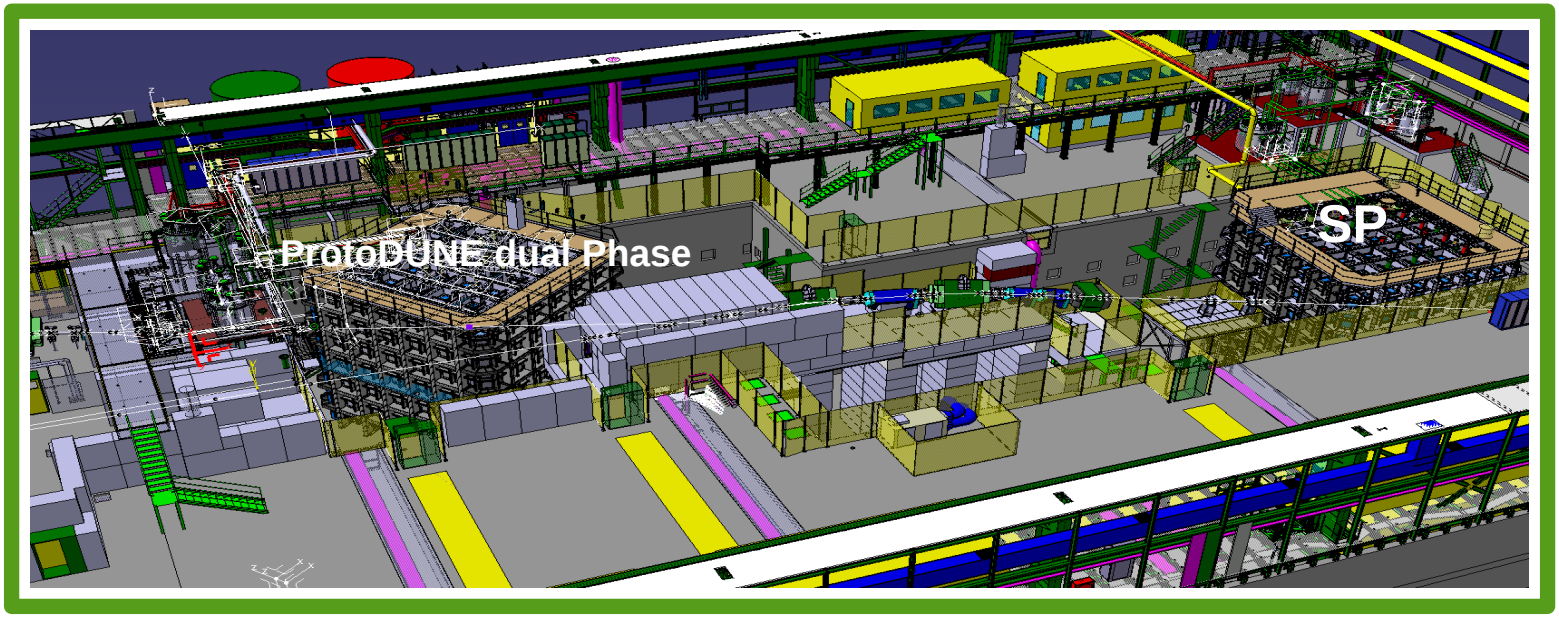
The WA105 protoDUNE LArTPC (6x6x6 m3) is one of the far detector technology option foreseen for the DUNE experiment

The WA105 protoDUNE DP

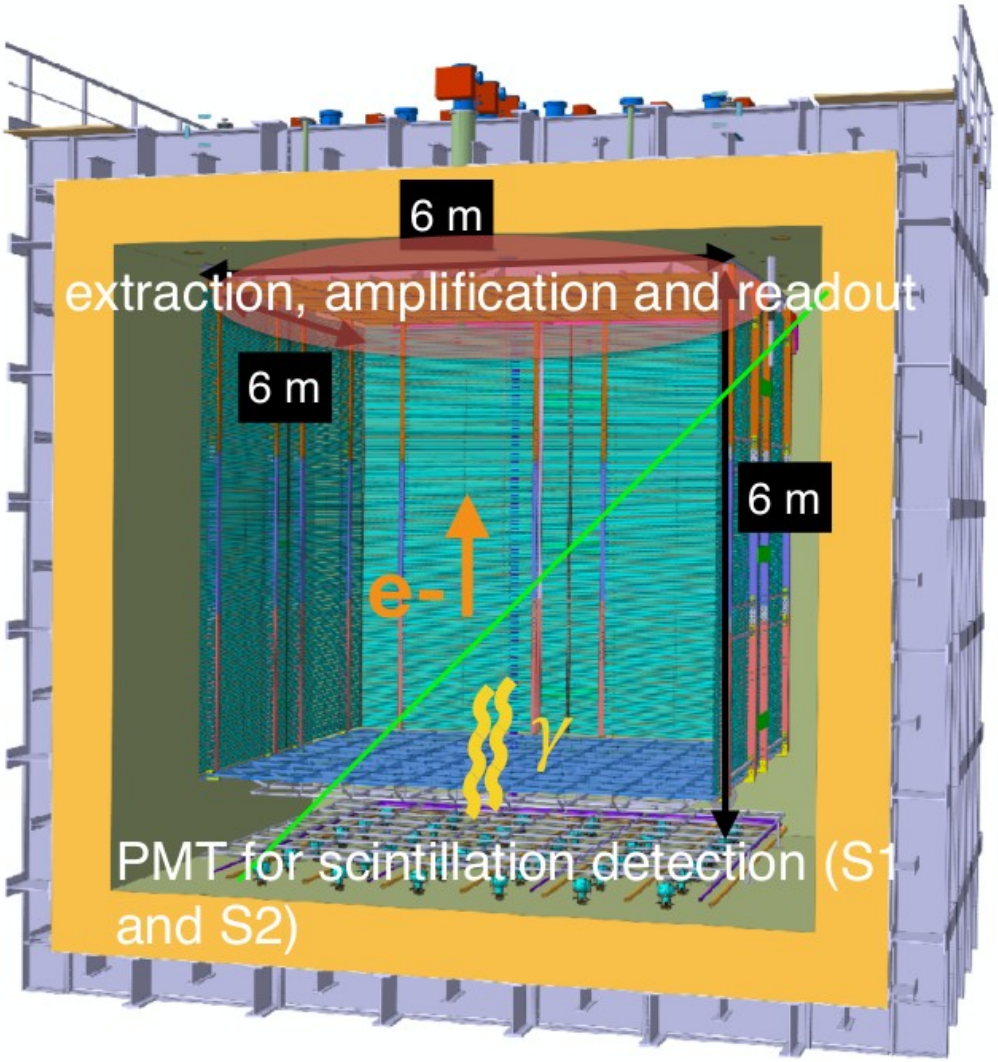




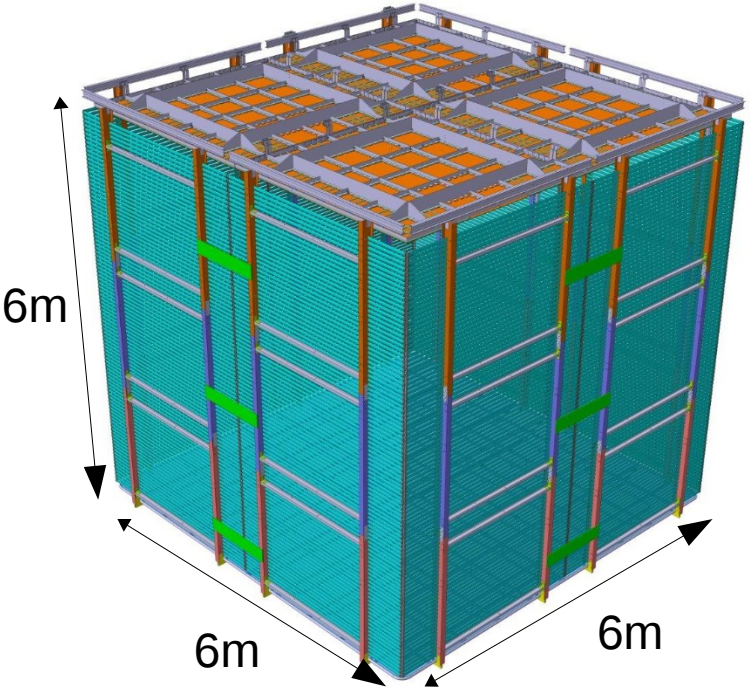
Where LAr-DP is



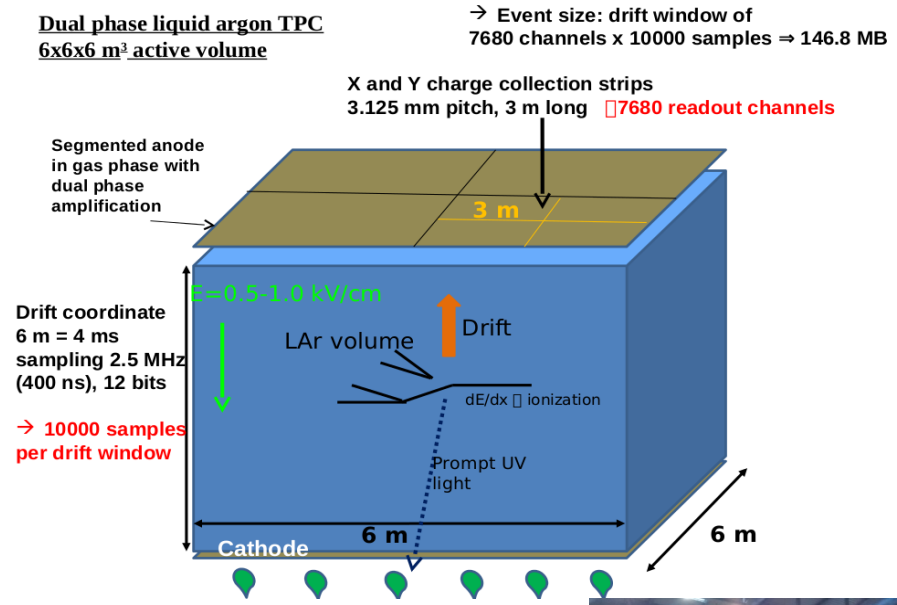
The Dual-Phase protoDUNE



The protoDUNE dual-phase/WA105 6x6x6 m^3 detector is the engineering prototype of the far detector technology options foreseen for the DUNE experiment



ProtoDUNE Dual-Phase: Towards the 10kton Dual Phase

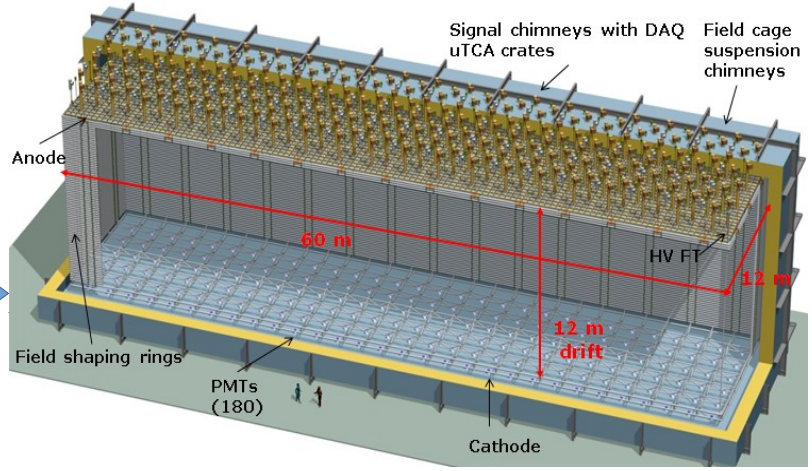


Physics program :

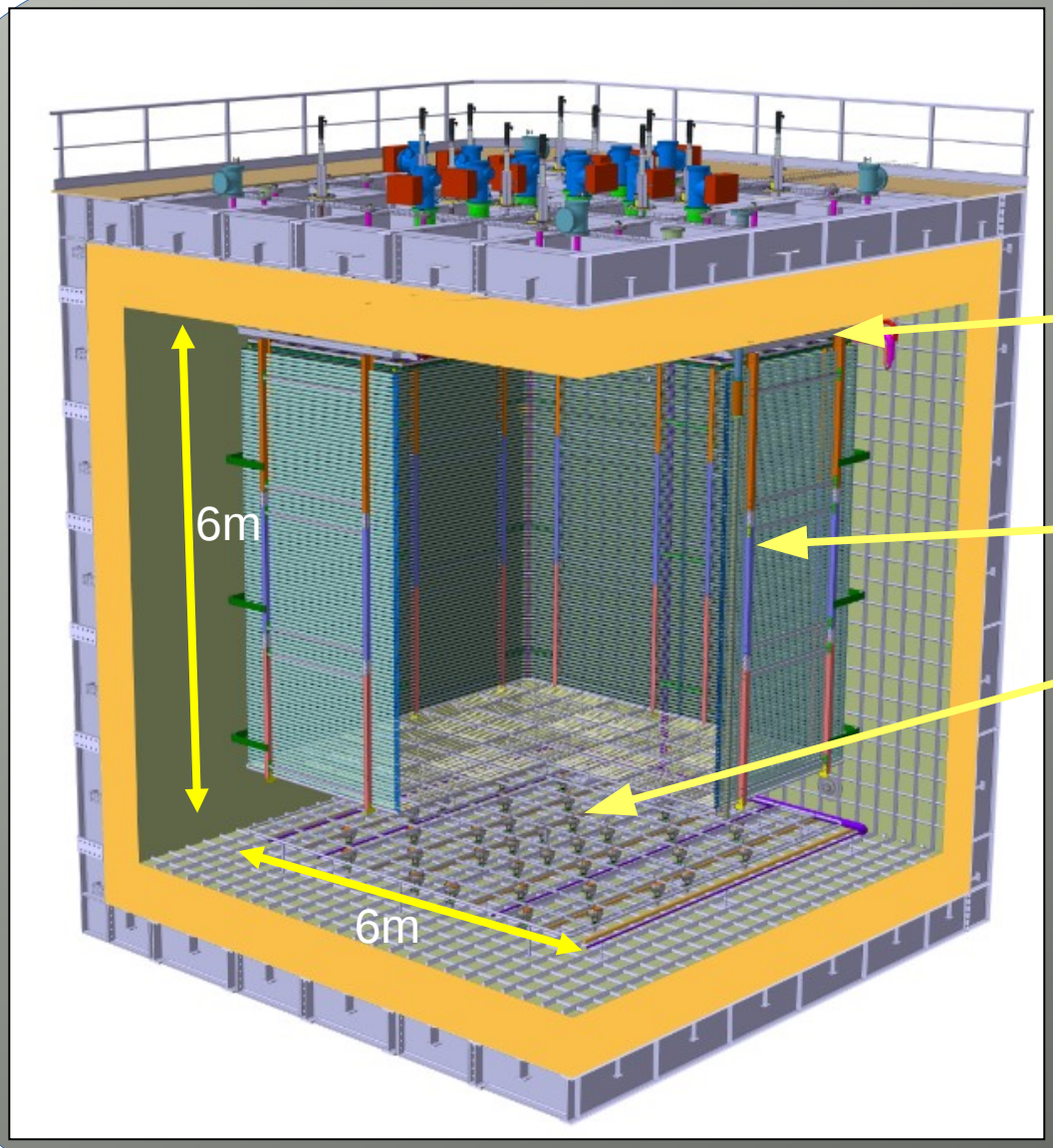
- em/hadronic calorimetry
- Cross-section measurement
- Reconstruction of pion and neutrino interactions
- Systematics for far detector

Dual-Phase DUNE FD: 20 times replication of Dual-Phase ProtoDUNE (drift 6m → 12m) DUNE Conceptual Design Report, July 2015

Active LAr mass:12.096 kton, fid mass:10.643 kton, N. of channels: 153600



Detector-Cryostat system



Charge Readout planes:

Field Cage

Cathode:
*** Transparent**
*** made up with SS tubes**
***Ground grid above PMTs**

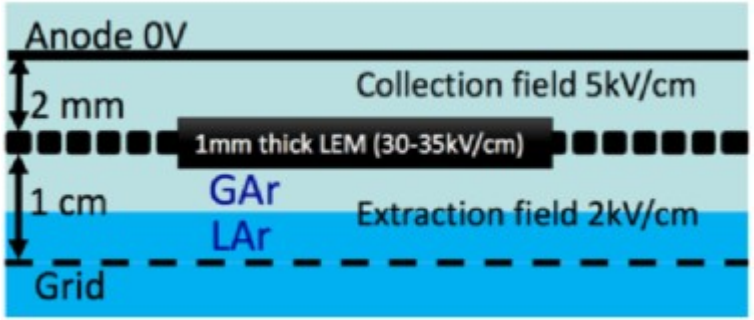
Full 3D electrostatic simulations completed for HV feedthrough, field-cage, cathode, ground grid

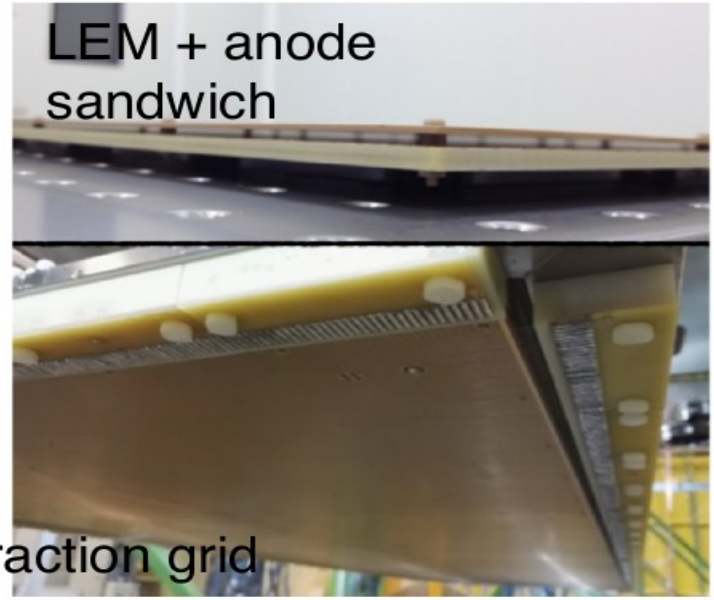
Charge Readout Plane

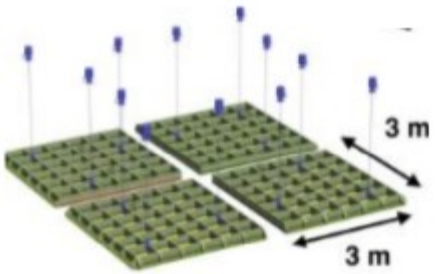
- The grid that provides the charge extraction from liquid to gas, the LEM amplification devices and the anodes are all mounted on specifically designed frame called **Charge Readout Plane (CRP)**

- The **CRP** is designed to precisely maintaining the interstage distances between grid, LEM and anode

- The CRP is modular and independent from fiel cage



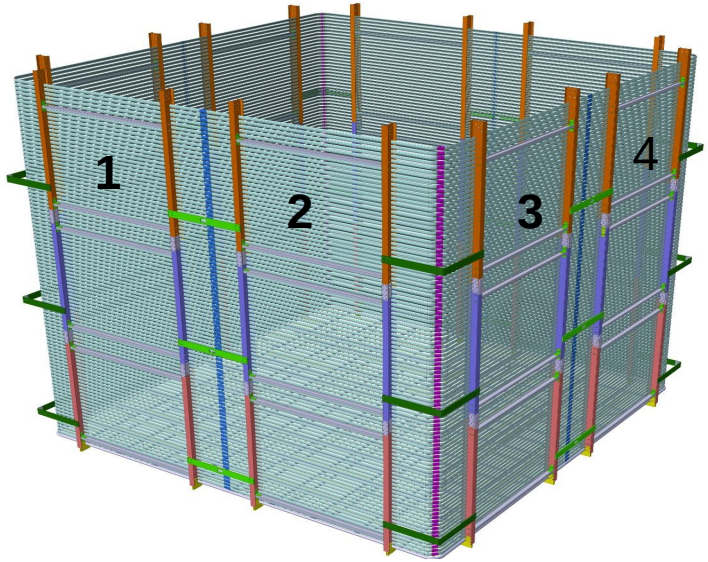


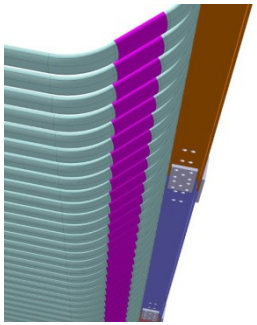


WA105: 4 CRP

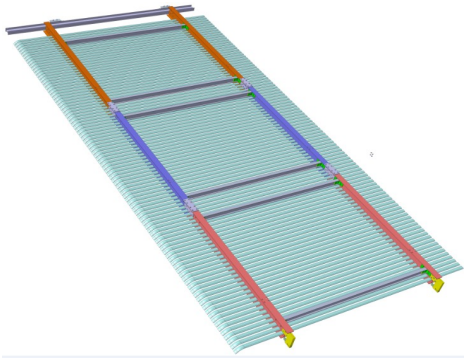
Field Cage design

- Field cage shares common basic structural elements w/ protoDUNE-SP
- Consists of 8 vertical modules of 6310 x 3010 mm^2 (2 modules per detector face)
- Each module is assembled out of 3 distinct sub-modules
- 11 profiles with one end bent at 45 degrees are electrically connected by 2 HV divider boards
- 98 electrically continuous rings in 60mm pitch using straight aluminum clips
- Three distinct types of sub-modules with 33, 33, and 32 profiles each held by a frame with two 6” and two 3” horizontal FRP I-beams





Clips connection

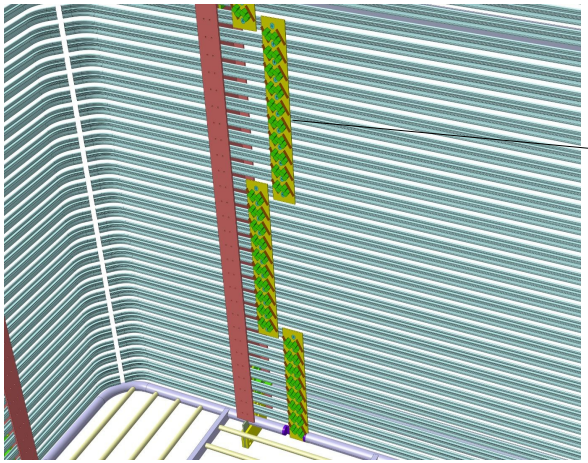


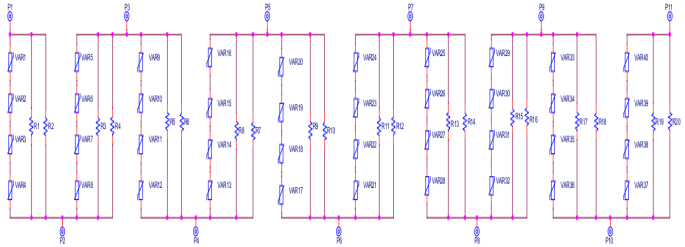
3 sub modules

Sub-module zero built at UT Arlington

High Voltage Divider Board :

- Each divider board connect 11 profiles total
- Top and Bottom profiles of the 11 profiles will have two boards connected each, completing the circuit
- Total number of the board needed: 20
- Electrical components on each board
  - Two 2GW resisters (rated 20kV, 1%, 2.5W, -55°C) in parallel each stage, 1GW effective resistance
  - Four varistors with 1.8kV nominal clamping voltage each, giving 7.2kV clamping voltage in series for circuit protection
  - Varistor string is connected to the resisters in parallel



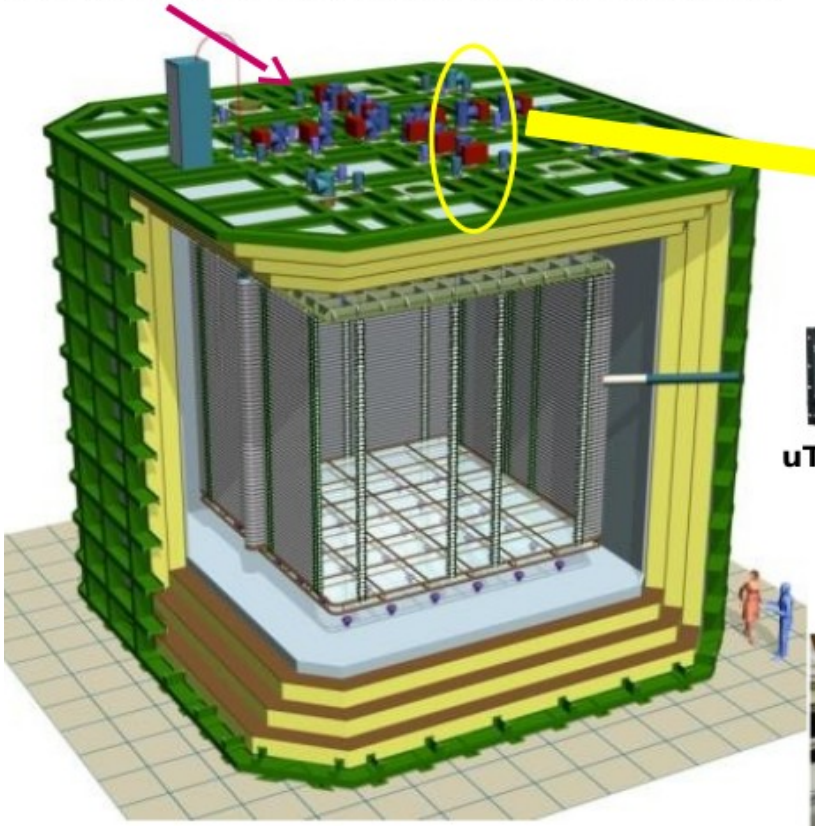


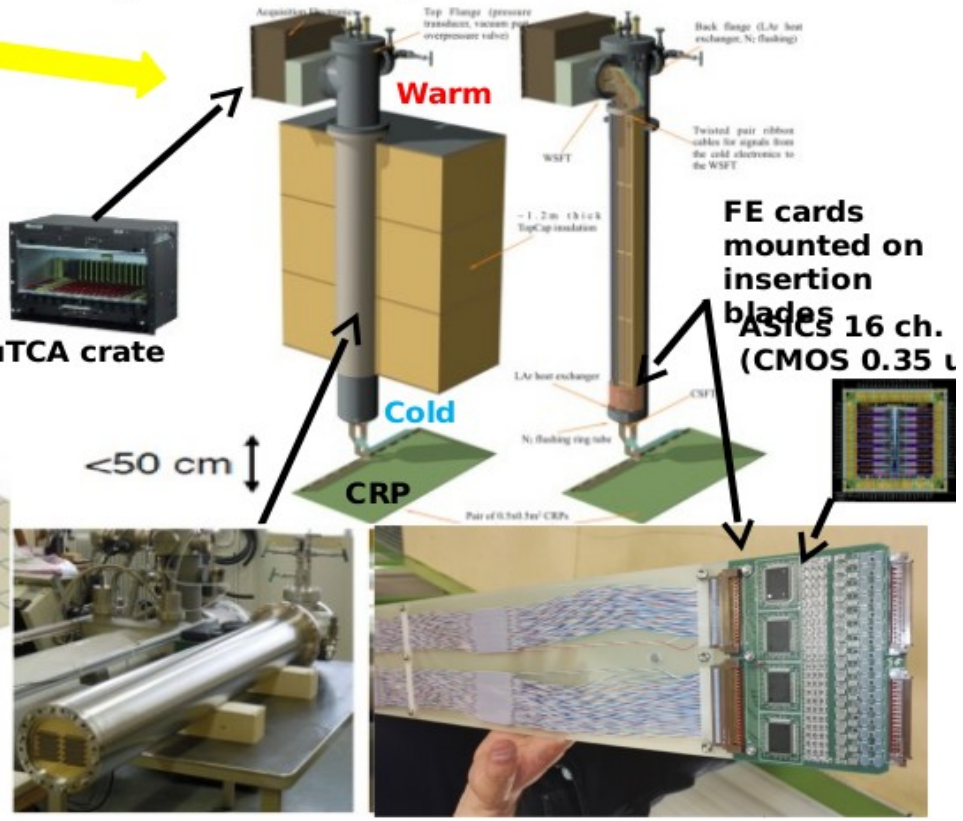
Circuit diagram a HV divider board

Electronics and DAQ

Full accessibility provided by the double-phase charge readout at the top of the detector

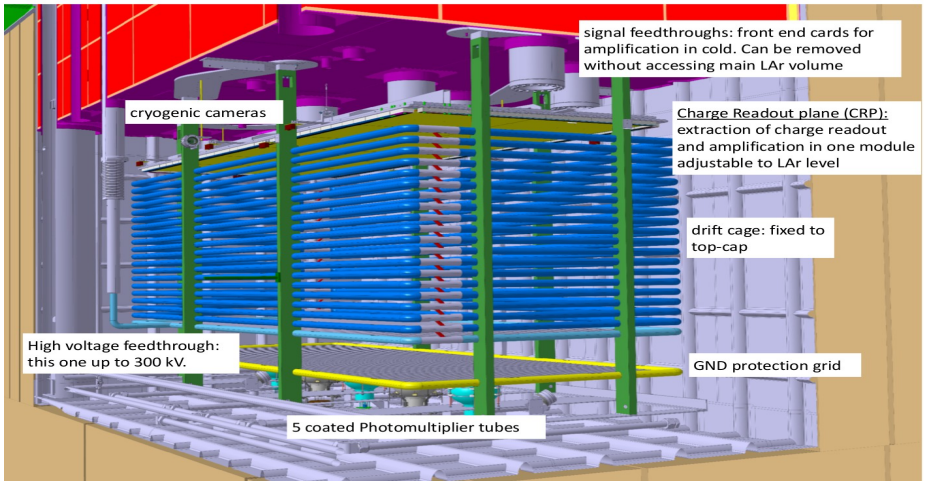
- **Digital electronics at warm on the tank deck:**
  - Architecture based on uTCA standard
  - 1 crate/signal chimney, 640 channels/crate
  - 12 uTCA crates, 10 AMC cards/crate, 64 ch/card
- **Cryogenic ASIC amplifiers (CMOS 0.35um) 16ch externally accessible:**
  - Working at 110K at the bottom of the signal chimneys
  - Cards fixed to a plug accessible from outside
  - Short cables capacitance, low noise at low T



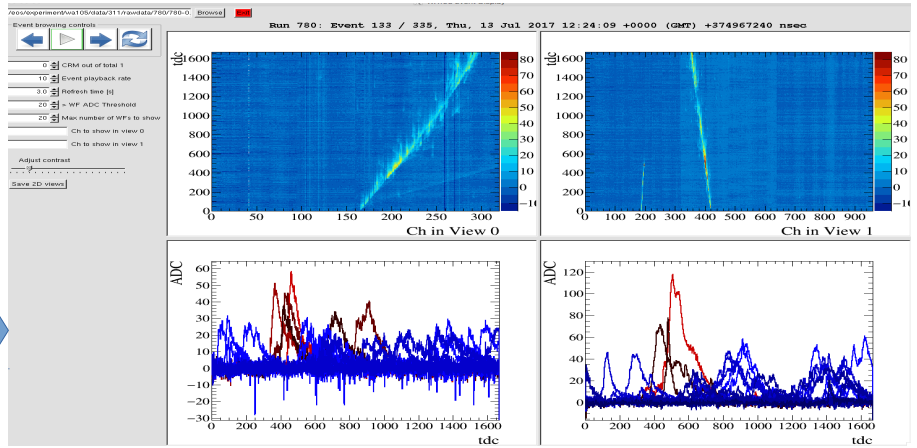


3x1x1 Dual Phase LArTPC pilot detector

- **3x1x1 m3 detector is the pilot project for protoDUNE DP**
  - ✔ **Smooth installation according to schedule, no major issues**
  - ✔ **Fully engineered version of many detector components for protoDUNE DP**
  - ✔ **First overview of complete system integration**
  - ✔ **Successful piston purge and cooling**
  - ✔ **Started taking data from June 2017**



Successful of getting Cosmic events platform setup for protoDUNE DP



Events with PMT trigger

Status

- Success of 3x1x1 catalyzing progress on 6x6x6
- The protoDUNE dual-phase is in an advanced state of construction
- Fully engineered versions of many detector components with pre-production and direct implementation are in place
- First overview of the complete system integration: set up full chains for QA/QC, construction, installation, commissioning
- The executive design of the CRPs, Field Cage, cathode, was completed by the end of November 2016. The schedule has been revised by taking into account final design and precise operation sequences, availability of infrastructure , experience from 3x1x1 assembly, follow up of orders and tendering.
- The protoDUNE dual-phase passed final design review and production readiness review
- Anticipate legal and practical aspects related to procurement, costs and schedule verification
- Installation and cabling in cryostat in March 2018

Conclusions

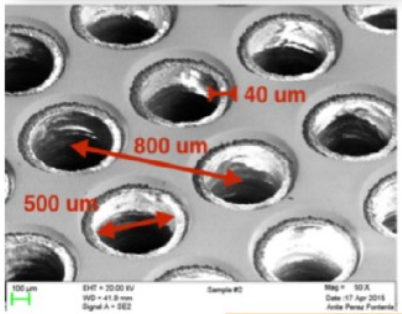
- Dual Phase LArTPCs are one of the far detector technology options foreseen for the DUNE experiment
- The protoDUNE Dual Phase will not only serve as the engineering prototype of the FD, but will also demonstrate the concept of large dual phase LArTPC
- The protoDUNE-DP passed final design review and PRR, in a stage of production of the components
- 3x1x1 dual phase pilot detector successfully installed and started taking cosmic data
- The 3x1x1 pilot detector has been extremely useful in order to reach an advanced state of prototyping and costs assessment of most of the components for the 6x6x6 and to anticipate legal and procurement problems
- The protoDUNE dual-phase construction is in an advanced state and largely benefited of the preparation activities/experience with the 3x1x1. We are looking forward to the completion of the DP protoDUNE detector assembly in the cryostat and running with great success

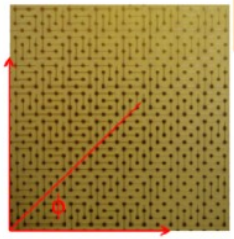
Thank you

Backup

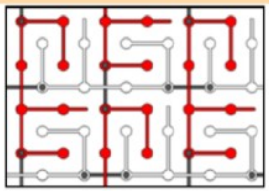
DP test

10x10cm^2: LEM/anode R&D

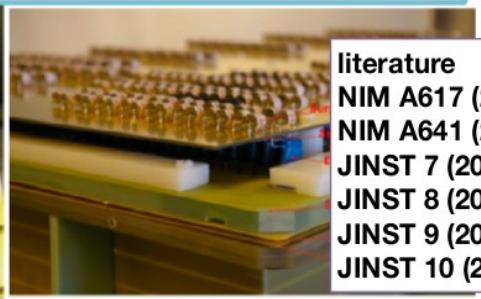




dC/dl ~ 120 pF/m

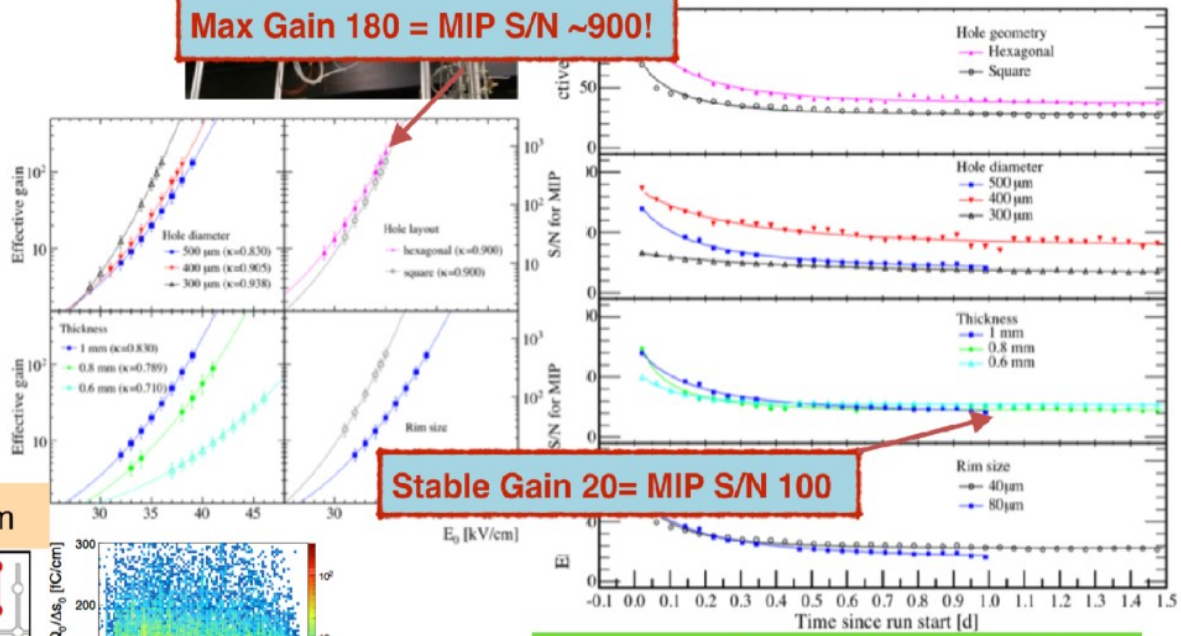


40x80cm^2: stable operation of large area readouts

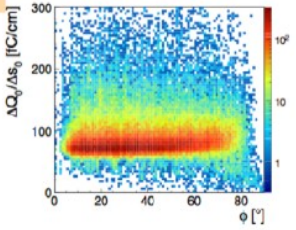


literature
NIM A617 (2010) p188-192
NIM A641 (2011) p 48-57
JINST 7 (2012) P08026
JINST 8 (2013) P04012
JINST 9 (2014) P03017
JINST 10 (2015) P03017

Max Gain 180 = MIP S/N ~900!

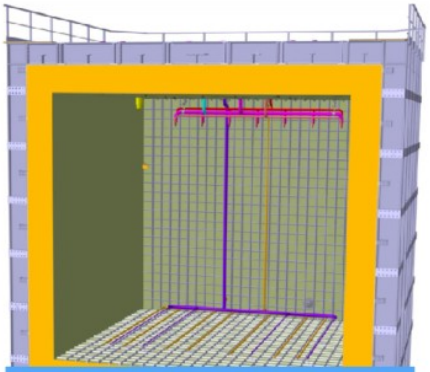


Stable Gain 20= MIP S/N 100

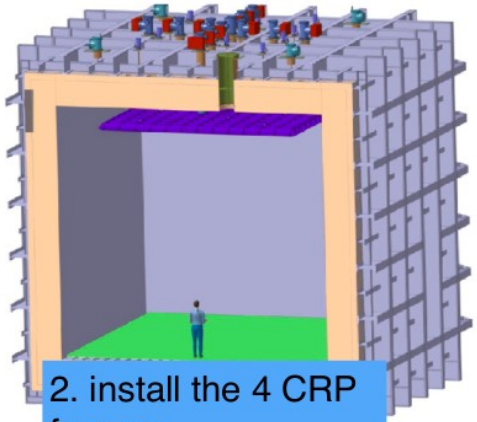


Operating with amplification of about a factor 20

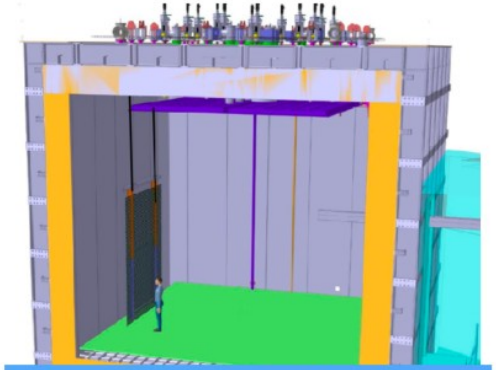
DP installation Sequence



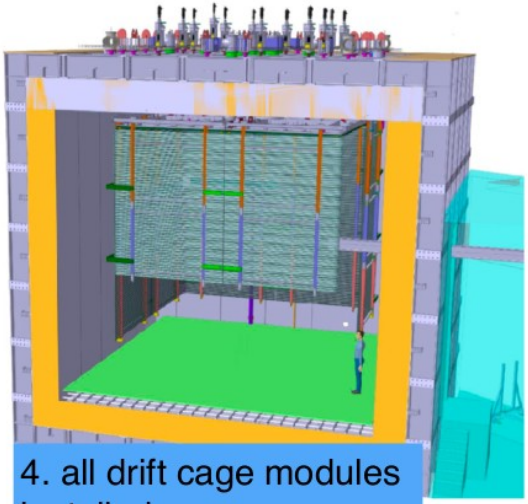
1. install internal piping & temporary floor



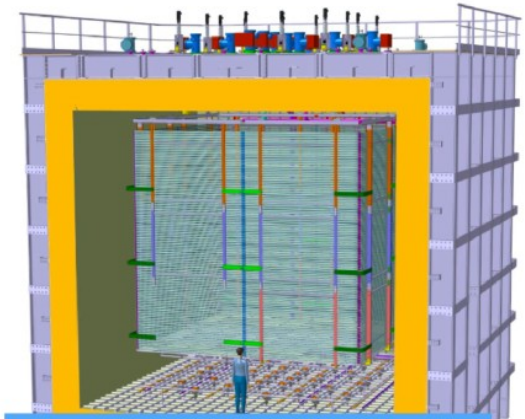
2. install the 4 CRP frames



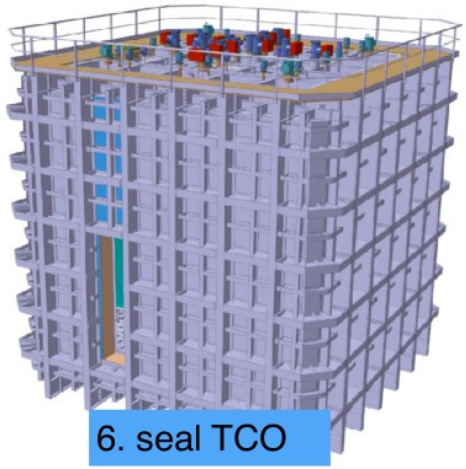
3. install the first drift cage modules



4. all drift cage modules installed



5. remove temporary floor and install photomultipliers



6. seal TCO